EXISTENCE OF THE ω^0 PARTICLE*

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(Received February 20, 1961)

Recent experiments by Abashian, Booth, and Crowe[1] on the p-d reaction have been interpreted as an indication of the existence of an ω^0 particle (boson) having an isotopic spin of $I=0$ or $I=1$ (probably the former), a mass in the neighborhood of 305 Mev, and a rather long lifetime for decay into pions (width less than 16 Mev). It has already been remarked[2] that such a state of the two-pion system appears to be inconsistent with the pion energy distribution in τ decay. We would like to point out that the existence of <u>either</u> a two-pion <u>or</u> a (bound) three-pion state[3] of angular momentum $J=0$ or $J=1$ at this energy would appear to be inconsistent with observations on the K^+-decay modes. The point is that the decay process

$$K^+ \to \omega^0 + \pi^+ \tag{1}$$

could occur and would have the appearance of an anomalous (2π) decay mode of the K^+ when the ω^0 decayed into neutral particles (such as a π^0 and γ). Estimates of the branching ratio for this process which are given below indicate that it is of the same order or larger than the branching ratio for K_{e3} decay; hence it should have been readily detected and has not been.

In order to estimate the branching ratio for process (1), we first assume that the ω^0 has spin 0 so that the decay into an S state is allowed. Since $|\Delta I| = \frac{1}{2}$ is possible for (1), the process is very similar to the 2π decay mode of the <u>neutral</u> K meson. If it is assumed that the coupling is about the same for the two modes, the ratio may be estimated on the basis of the available phase space:

$$\frac{W(K^+ \to \omega^0 + \pi^+)}{W(K_1{}^0 \to \pi^+ + \pi^-)} \approx (q/p) = 0.45, \tag{2}$$

where W is the transition probability and q, p are the magnitudes of the momenta of the ω^0 and π^-, respectively. Equation (2) indicates that the K^+ lifetime would be nearly as short as the $K_1{}^0$ lifetime, which is quite clearly contrary to the observations. Since the lifetime ratio is about 100 and the branching ratio for the anomalous mode of the K^+ is presumably much less than 10%, the above estimate would need to be in error by a factor of at least 10^3 to permit the existence of the spin-0 state. Although the estimate is crude, it does not seem likely that the errors are so large as that.

If the ω^0 has a spin of 1, the final state in reaction (1) is a P state and the centrifugal barrier may reduce the ratio from the value given by Eq. (2). In order to estimate the effect of the barrier, it is necessary to introduce a range $r_0 = \lambda^{-1}$ for the interaction in the decay. We then find

$$\frac{W(K^+ \to \omega^0 + \pi^+)}{W(K_1{}^0 \to \pi^+ + \pi^-)} \approx (q/p)(e_\mu K_\mu/\lambda)^2,$$

where e_μ is the polarization vector of the ω^0 and K_μ the four-momentum of the K^+. After summing over directions of polarization, we find

$$\frac{W(K^+ \to \omega^0 + \pi^+)}{W(K_1{}^0 \to \pi^+ + \pi^-)} \approx (m_K/m_\omega)^2 (q/p)(q/m_\pi)^2 \approx 0.5(m_\pi/\lambda)^2, \tag{3}$$

where m_K, m_ω, and m_π are the masses of the indicated particles.

Ogawa[4] has demonstrated that an interaction range corresponding to $\lambda \approx \frac{1}{2} m_\pi$ is suggested by the branching ratios for nonleptonic decay of the strange particles. However, even if we are much more conservative and take $\lambda = M$, the nucleon mass, the ratio Eq. (3) becomes 10^{-2} which is still much too large to have escaped detection.

Because in the case that ω^0 has spin 1 the above comparison involves the relationship between a scalar (for the π) and vector (for the ω) coupling, it is desirable to make an estimate on an entirely different basis. Since the weak electron-neutrino current is a vector current, we have estimated the ratio of the rate of (1) to the K_{e3} decay rate on the basis of the diagrams shown in Fig. 1. The bubble in the ω^0 line of Fig. 1(b) is taken to be a nucleon-antinucleon bubble and the weak coupling of this bubble to the black box is assumed to have the same form as the leptonic coupling. In this way we find

$$\frac{W(K^+ \to \pi^+ + \omega^0)}{W(K^+ \to \pi^0 + e^+ + \nu)} \approx 7.5 \times 10^2 \pi (\delta m_\omega / m_K)^2 \times (q/m_K)^3 (G^2/4\pi)^{-1} (f/f')^2, \tag{4}$$

where δm_ω is the mass shift of the ω^0 due to the nucleon bubble, G is the strong coupling between

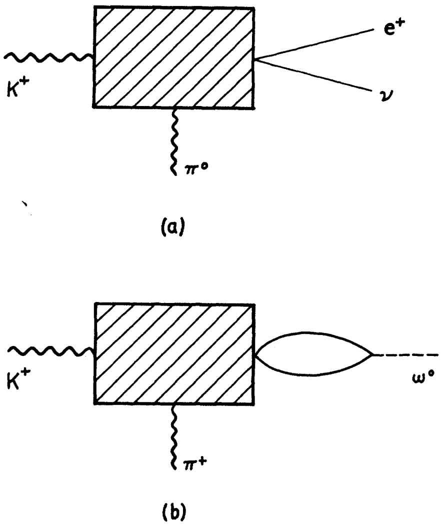

FIG. 1. Diagrams of the related processes for K^+ decay. The loop in Fig. 1(b) is a nucleon-antinucleon loop.

the ω^0 and nucleons, and f and f' are the weak-coupling constants for nucleons and leptons, respectively. An estimate of G has been given by Sakurai[5] on the assumption that a neutral vector boson is responsible for the spin-orbit force in p-p scattering. The value obtained in this way depends on the mass of the boson. By extrapolating his results as a function of the mass to the value m_ω, we estimate $G^2/4\pi \approx 2$. To obtain δm_ω, we make a Goldberger-Treiman[6] type of analysis of the matrix element of the weak interaction current of the ω^0, including just nucleon-antinucleon states. The result is $\delta m_\omega^2 \approx m_\omega^2$. Then Eq. (4) becomes

$$\frac{W(K^+\to\pi^++\omega^0)}{W(K^+\to\pi^0+e^++\nu)}\approx (f/f')^2. \tag{5}$$

We may take $f \approx f'$ although there is some reason to believe[7] that $(f/f')^2$ is larger than one. Thus, we find that the anomalous decay mode should be competitive with the K_{e3} mode, which again is much too large a rate. Since Fig. 1(b) describes only one of the possible decay mechanisms, it seems likely that the estimate given by Eq. (5) is quite conservative.

While we recognize that arguments of the kind presented here are subject to some doubt, they certainly suggest[8] that there does not exist an ω^0 particle composed of pions and having the mass observed in the experiment of Abashian *et al.*[1]

However, these arguments do leave open the following possibilities:

(1) An ω^0 state of the pions exists but has a spin greater than 1.

(2) An ω^0 particle with spin 0 or 1 exists but its interactions with pions are not very strong.

(3) The observed effect is merely a manifestation of a normal energy dependence of the matrix element, as suggested by Tubis and Uretsky[9] and by Greider.[10]

A careful examination of the energy spectrum of the charged pion in (apparent) τ' decay would be of interest in this connection since the process (1) would cause a narrow line to be superimposed on this spectrum.

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[*] This work was supported in part by the U. S. Atomic Energy Commission and in part by the University of Wisconsin Research Committee with funds provided by the Wisconsin Alumni Research Foundation.

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[8] An argument against the interpretation of these experiments in terms of a strongly coupled $T=0$, $J=1$ particle may be taken from G. Breit, Phys. Rev. 120, 287 (1960), where it is suggested that the mass of such a vector boson must be considerably greater than m_ω in order to be consistent with the nucleon-nucleon forces.

[9] A. Tubis and J. L. Uretsky, Phys. Rev. Letters 5, 513 (1960).

[10] K. R. Greider (private communication).